The Use of GIS in Studying Benthic Marine Animal Movement and Habitat Use

Understanding the relationship between marine species and their habitats is a fundamental step in developing more realistic models to assist in fisheries management techniques. In 1996, Congress amended the Magnuson-Stevens Fishery Conservation and Management Act with a measure calling for the inclusion of essential fish habitat into fisheries management (NOAA, 1996). As a result of this amendment, there has been an increase in the number of studies concentrating on the various methods in which habitat use can be assessed in a marine environment. Perhaps one of the youngest, yet most promising ways to predict and test habitat use is through the application of GIS tools and analyst models.

The study of animal movement has long been used to determine habitat use and home ranges of benthic species. Fishery managers are beginning to use studies that incorporate fish and invertebrate movement into their assessment of essential fish habitats. GIS is an ideal tool to select for use because it provides the ability to map not only species movement spatially and temporally, but also the power to model species distributions and habitat selectivity. Thus, I find it very interesting that despite a thorough literature search, I found only one example of GIS use in studying benthic marine animal movement (Hooge, Eichenlaub and Solomon, 2001). It is intriguing, however, that many papers are being published that study movement and habitat use through ultrasonic telemetry or mark and recapture experiments (examples: Gonzalez-Gurriaran & Freire, 1994; Comeau & Savoie, 2001, Hoyt et. al., 2002). These studies, however, did not use GIS in their analyses; yet it is clear that their work would benefit from the new technology. This gap in the literature, nonetheless, is bound to be filled with new research incorporating movement and habitat variables into GIS to model fish and invertebrate distributions (Taggart and Hooge, pers. com.). For example, new extensions for ArcView have been or are being created to encourage future researchers to include animal movement in their GIS applications (Hooge, Eichenlaub and Solomon, 2001).

Instead of focusing on a combination of GIS, animal movement, and habitat use, researchers and managers have turned to GIS to predict fish distribution through the development of habitat suitability index (HSI) models or some variation of this model form (Isaak and Hubert, 1997; Rubec et. al., 1998; Brown et. al., 2000; Appeldoorn et. al., 2001; Stoner et. al., 2001). HSI models (or similar variations) take different habitat variables, usually in raster format, and overlay the data to create a single distribution map predicting the most suitable areas of habitat for a particular species (Rubec et. al., 1998). For example, Brown et. al. (2000), overlaid depth, salinity, temperature, and substrate together across different seasons for 2 different life stages of the softshell clam, Mya arenaria. The authors predicted from the final suitability map that adult and juvenile clams were most likely to be found in the summer in shallow areas (intertidal to subtidal) around the shoreline or islands. The strength behind this type of model is that the predictions are easy to test in the field or with previously collected CPUE or fishery independent data. Brown et. al. (2000), for example, tested their predicted clam distributions with data from the Maine Yankee clam survey and found that their species distribution predictions were correct. The authors, however, did point out that when using fishery dependent data, one must take into account that areas of predicted non-suitable habitat are less likely to be fished (due to the low yield) than areas of high habitat quality. This leads to a gap in the data used to test the predictions of the model. Therefore, it may be beneficial to sample independently and collect distribution data from both high and low habitat suitability areas to provide a more well-rounded picture of true species distribution and habitat use.
Another advantage to HSI modeling is the ability to overlay the predicted habitat use maps for individual species into a single map for all species. This allows managers to look for and protect habitat hotspots, or areas where all target species use the same habitat. Brown et al. (2000), combined eight predicted distribution maps into a single map for each season. The resulting maps demonstrated that for all eight species, at almost all the different life history stages, Portland Harbor and the mouths of the Presumpscot and Royal rivers are extremely important habitats. These models did not include the effect of pollution on the distribution of these species. However, by removing the pollution effect, it is clear that these areas are of critical importance to the local stocks. This paper presents a nice demonstration of how HSI modeling can be used to target areas that should be considered for ecological restoration and preservation.

A common problem with this type of modeling is the lack of consideration of the effect of interspecific and intraspecific interactions on species habitat use and spatial distribution. Only one paper in my review considered the effect of prey density on their target species, juvenile winter flounder (Stoner et. al., 2001). Other authors, that did not include these interactions in their predictions, simply mentioned that future studies should incorporate behavioral ecology and predator/prey distributions into their HSI modeling (Brown et. al., 2000). Stoner et. al. (2001) set a nice example in their study, where the prey density of the flounder was simply inputted as another layer into their modeling. The prey density, indeed, had a large impact on the significance of the model, creating a better fitting model on flounder distribution. However, to further the findings of this research and others, it would be prudent to include the density of predators into modeling.

GIS is already being used to map animal movement and determine habitat use for terrestrial animals and for large marine organisms that tend to spend time on or near the surface of the water (whales, tuna, turtles, etc.). With the development of new technologies, it is now becoming possible to begin recording the movement of benthic marine animals for analysis in GIS. The use of HSI modeling, or variations of this model, combined with new extensions and tools in GIS on movement and home ranges will provide managers with the ability to make well-informed decisions based upon the knowledge of the multiple variables impacting benthic fish and invertebrate habitat use.

References:


Rubec, P.J., M.S. Coyne, R.H. McMichael, Jr., & M.E. Monaco. 1998. Spatial methods being developed in Florida to determine essential fish habitat. Fisheries 23 (7): 21-25.


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Annotated Bibliography

Appeldoorn, R.S., K. Foley, E. Molina, & C.W. Recksiek. 2001. Benthic mapping from fish and habitat transect data using GIS technology. Proc. Gulf Carib. Fish. Inst. 52: 674-685. One of the most commons methods used for assessing fish abundance and habitat characteristics is the visual transect (usually conducted by divers). These authors developed a method for converting visual transect data into spatially referenced data on an, ecologically-speaking, larger scale. I expected this paper to provide not only understandable descriptions of their methodology, but also a solid example of the feasibility of extending these data out to a broader ecological scale. Instead, this paper briefly mentioned that they correlated fish density with habitat type and then never presented their fish diversity results, I had trouble understanding some aspects of their GIS use, and only one field example was provided from a small section of a Puerto Rican reef. I agree with the authors, however, that it would be extremely beneficial to the scientific community to develop a method for integrating visual transect data into GIS and I would expect that these authors are currently trying to devise more simplistic ways to address this issue.

Brown, S.K., K.R. Buja, S.H. Jury, & M.E. Monaco. 2000. Habitat suitability index models for eight fish and invertebrate species in Casco and Sheepscot Bays, Maine. North American Journal of Fisheries Management 20: 408-435. This paper developed habitat suitability models (HSI) for eight benthic and pelagic species in Maine. The authors incorporated the physical characteristics of the study area into their modeling and their knowledge of the life history stages of the selected species to map the importance of various areas within the bays. The model’s predictions were tested with previously collected CPUE data from multiple sources. It was nice to see such an extensive analysis, incorporating most life history stages and various physical factors into modeling HSI for the targeted species. This paper should provide other scientists with a baseline to follow when developing HSI models for their region. Additionally, I appreciated the fact that the
authors recognized the majority of the faults in their study and suggested ways to enhance models and improve upon their example. The research also demonstrates that solid scientific findings can be derived from previously collected data when these data are combined with the simple, powerful methods of modeling in GIS.


These authors developed a method to analyze animal movement in GIS by incorporating various models and analysis tool packages into their ArcView extension. This paper describes the new extension and clarifies the different models used to calculate home ranges and understand animal movements. An example was included using data from a sonic-tracking study of Pacific halibut in Glacier Bay, Alaska. In order to develop a better understanding of marine animal habitat use and preferences, it is extremely important to incorporate movement studies into research. This paper provides authors with a good starting point to using the Animal Movement Analyst Extension and developing a better understanding of their respective fish or invertebrate species. Other layers, such as substrate, bathymetry, and currents could also be incorporated into the analysis to create a well-rounded picture of the species habitat use patterns.


Two major types of data collection were utilized to determine habitat selectivity by rockfish (Sebestes sp.). The first method involved manned submersible dives, with a trained observer conducting fish counts and collecting substrate data. The second method utilized sonar imagery to create a map of Heceta Bank’s seafloor. These data allowed for the development of habitat “patches” available in the bank. The patches, in turn, are associated with the species of rockfish found on those particular substrate and relief types. Fishery managers can now utilize these data to predict what fish species may be found in what area depending on substrate and relief. It is important, however, to recognize that these data assume that the studied rockfish remain in close association with the benthos, whereas, some of the studied species are known to spend much of their time far above the substrate in the pelagic zone.

Rubec, P.J., M.S. Coyne, R.H. McMichael, Jr., & M.E. Monaco. 1998. Spatial methods being developed in Florida to determine essential fish habitat. Fisheries 23 (7): 21-25.

In this paper, the authors give a nice overview of methods they are developing to determine suitability indices of various estuarine habitats for different fish and invertebrate species in Florida. Habitat suitability index models (HSI) overlay several types of environmental data in a database to create predicted species distribution maps. This report provides other managers with the chance to learn, before the final results are published, how to begin analyzing spatial information for use in predicting essential fish habitat in their fisheries. A common problem with this paper, however, is that the authors focus upon habitat as the primary factor influencing species distribution. Interspecific interactions may also play an important role, therefore, a single species approach may provide misleading results. To make the model even more realistic, I would a consider integrating community-based methodology with habitat data.

These authors modeled flounder habitat use with generalized additive models and GIS to predict and test (in the field) the distribution of different size classes of juvenile fish. It was found that habitat use changes with the size class of the fish and that the quantity of preferred habitat varies over time. The authors also included information on the abundance of prey for the various life stages of this flounder. This is the first example I've seen that incorporates interspecific interactions in their habitat use models. It is especially interesting that prey abundance had a significant effect on flounder habitat use. Considering the impact prey items have on flounder, it probably would have been beneficial to also consider the effect and abundance of flounder predators in the estuary. Overall, this paper is an excellent example of the use of GIS in modeling, mapping and predicting habitat use of benthic marine species.


Using catch data from fisher’s logbooks, weathervane scallop aggregations were mapped using GIS in Alaskan waters. These data were used to infer the preferred sediment type and depth of the invertebrate. There are numerous limitations and advantages of using data from fishers. There are obvious advantages in using data collected across a wide geographic range for a single target species and in the involvement of fishers in the science used to manage their catch. However, these data were limited in their scope; depths were only recorded from the beginning of each tow (not throughout the tow), and small scale maps were used for sediment types leading to the possibility of larger error. It was found that, converse to most other scallop species preferences, the weathervane scallop preferred silty and sandy substrates. It is difficult to determine if these preferences are true to the species, or if they appear because of sediment preferences for fishing gear or because no sediment data was collected along the actual dredging path. Despite this, the paper is a good start to using valuable data collected from fishers, in concert with GIS to determine preferred habitat and fishing grounds.